	Found.	Calculated.
SiO_2	33·33	33·35
BaO	48·48	48·20
Al_2O_3	6·06	6·02
B_2O_3	12·12	12·40
	99·99	99·97

Specimen XXIV.

The "Jena" glass is essentially a borosilicate of zinc, soda, and magnesia, containing

$$20SiO_2,2ZnO,2MgO,3Na_2O,2B_2O_3.$$

	Found.	Calculated.
SiO_2	67·87	68·05
ZnO	9·03	9·11
Na_2O	10·04	10·46
MgO	5·02	4·50
B_2O_3	8·03	7·87
	99·99	99·99

"On the Magnetic Deformation of Nickel." By E. Taylor Jones, D.Sc. Communicated by Professor Andrew Gray, F.R.S. Received February 8,—Read February 17, 1898.

On a former occasion a paper was communicated to the Royal Society* containing an account of some measurements of the magnetic contraction of a nickel wire, and a comparison of these with the values deduced from Kirchhoff's theory. It was there shown that the most important term in the calculated value of the elongation of a long wire of soft magnetic metal is represented by $\frac{1}{2}H(\delta I/\delta P)$, where H is the magnetising field and δI the increase of magnetisation produced by a small increase of longitudinal tension δP per unit area. The results showed that the observed contraction in nickel was much greater than the calculated value. It was then sought to establish an empirical equation which might represent the observed effects, and it was found that the difference between the observed and calculated contraction was approximately proportional to the fourth power of the magnetisation.

It was suggested to me at the time that this result should be tested by repeating the experiments under different conditions in order to find out whether it was generally true.

* 'Phil. Trans.,' A, vol. 189 (1897), p. 189.

In offering the following results, I wish again to say that the measurements were made in the Physical Laboratory of the University College of North Wales, and that I am greatly indebted to Professor A. Gray for providing me with the apparatus, and allowing me the time necessary for the experiments, and for many valuable suggestions.

Preliminary experiments were first made to find the nature of the influence of temperature on the magnetic contraction. The apparatus was essentially the same as described in the former paper, with the addition of a spiral tube and burner for heating the water just before it entered the coil. The temperature of the water on entering and leaving the coil was indicated by two thermometers inserted in capsules through which the water flowed. When the water was warmed and allowed to flow for some time, the two thermometers indicated steady temperatures differing generally by about 2° C.

The change of length was magnified by the same lever arrangement as before, and observed by a telescope, scale, and mirror. A few trials showed that it would be impossible to make any measurements when the water was warmed unless precautions were taken to remove air dissolved in the water, for this, on being liberated in the heater, ascended in bubbles through the coil and disturbed the apparatus so much that no readings could be taken. To prevent this, the water was made to flow into a vessel through a pipe near the top, and escape by a pipe near the bottom, whence it proceeded to the spiral heater. A tall glass tube projected upwards from the vessel, and the vessel was heated by a Bunsen flame. The dissolved gases were thus liberated in this vessel, and, collecting at the top, escaped at intervals up the glass tube. By this means the apparatus was rendered steady enough to admit of readings at moderately high temperatures. Further, by regulating the supply the water could be made to stand at any level in the glass tube. Thus the flow of water through the coil, and hence the temperature of the coil could be controlled.

The glass tube was about 6 feet long, and by raising the level of water in it through 1 foot the temperature of the coil was lowered by about 1° C.

Observations of the change of length were always made at night, generally between 10 P.M. and 2 A.M., the apparatus never being sufficiently steady in the daytime.

The nickel wire was the same as that used in the former experiments, of length 83·4 cm. between the terminal brass pieces, and mean diameter 1·65 mm. This was re-annealed before the present measurements.

A number of observations were then made of the change of length

and corresponding field strength on several nights in July and August, 1897, the temperature indicated by the coil thermometers being about 20° C. As before, the temporary and residual contractions were measured separately, the total contraction corresponding to any field strength being obtained as the sum of the temporary effect (observed as an elongation when the current was broken), and the residual effect observed by first demagnetising the wire by reversals, then quickly making and breaking the current. It was found that the curves thus obtained were not the same on different nights, but showed a continual diminution of contraction as time went on. This is probably due to a slow hardening of the metal which seems to go on for some time after the wire has been annealed. The effect of this change can be seen by comparing Tables I (column 2) and III (column 4), which contain values of the contraction of the wire in millionths of its length for a series of fields, observed about the middle of August, 1897, and at the end of December, 1897, respectively.* The wire was annealed on July 3, 1897.

In order to observe the effect of a change of temperature on the magnetic contraction at any field strength it was necessary to take readings at two temperatures immediately after one another, so that the results would not be affected by the above-mentioned time effect. This was done on several nights and with several field strengths, the two temperatures used being about 20° C. and 55° C. The results showed that at low fields (up to about 90 C.G.S.) this rise of temperature of 35° C. caused an increase, at higher fields a diminution, of contraction; and if the temperature was then lowered back to 20° C. the contraction returned to its former value.

Table I contains values of the change of length in millionths and corresponding field strength at the two temperatures, determined on two successive nights, the effect at both temperatures being observed at the lower fields on one night, and at the higher fields on the next. Each field was reversed several times before readings were taken, and the wire was demagnetised on each night while the temperature was being changed. The curves representing these results (contraction, field) have the same general form as was described in the former paper, but the temporary contraction is here considerably greater, though the residual contraction is much the same as before. The effect of temperature is chiefly seen in the temporary contraction: the residual effect, however, appears to be slightly less at the higher temperature at all fields.

On referring to Professor Ewing's 'Magnetic Induction in Iron and other Metals' (§ 114, p. 169), I find that rise of temperature causes increase of magnetisation in nickel at low fields and diminu-

* The temperatures on the two occasions differed by about 10° C., but the effect of this would be comparatively small.

tion at high fields. Change of temperature, therefore, seems to have similar effects on the magnetisation and contraction curves. Of course this comparatively small difference of temperature, 35° C., would have but a small effect on the magnetisation curve, but as the contraction seems to depend on rather high powers of the magnetisation, it might be expected that the effect would be more noticeable in the change of length than in the magnetisation.

Measurements were next made of the magnetisation and the effect of change of tension on the magnetisation, in order to calculate the quantity

$$\frac{0{\cdot}123}{10^{11}}\cdot \mathrm{I}^2+\frac{0{\cdot}00587}{10^{11}}\mathrm{IH}+\tfrac{1}{2}\mathrm{H}\frac{\delta \mathrm{I}}{\delta \mathrm{P}} \quad \ldots\ldots\ldots\ldots \quad (1),$$

which was shown in the former paper to be the value of the elongation, $\delta l/l$, of the wire deduced from Kirchhoff's theory. For these measurements a coil of 611 turns of No. 40 double silk-covered and shellacked copper wire was wound on the nickel wire near the middle, and connected in series with a ballistic galvanometer, and with the secondary of a standardising solenoid. The magnetisation was determined by reversing a measured magnetising current, and the galvanometer standardised by reversing a current in the solenoid, the deflections being observed in the two cases. The galvanometer was standardised before and after each set of readings.

Since the resistance in circuit with the galvanometer changed when the temperature of the coil on the nickel wire changed, care was taken that the temperature indicated by the coil thermometers was the same in the magnetisation and standardising experiments. By using a series of different currents in the standardising coil, it was verified that the "quantity of electricity" flowing through the galvanometer was proportional to the sine of half the deflection of the needle. The deflections were observed by a telescope and scale at a distance of 124 cm.

In observing the influence of tension on magnetisation, galvanometer readings were taken first with a load of 1·4 kg. on the wire, then after an additional weight of 7 kg. was applied. The magnetising current was reversed several times and the load applied and removed several times before readings were taken. This was repeated for various field strengths, ranging between 30 and 320 C.G.S., and with the coil at 10° C. and 55° C. Then the magnetisation curve of increasing reversals was determined for the mean load 4·9 kg. at both temperatures, after which the coil was removed from the nickel wire, and observations made with load 4·9 kg., and at the same two temperatures, of the magnetic contraction at a number of increasing field strengths, each field being reversed several times before readings were taken.

In order to make allowance for the slow time-change in the properties of the wire, the determinations of magnetisation and effect of change of tension on magnetisation were then repeated, the nickel wire being rewound with the same number of turns of insulated copper wire.

Finally, the contraction of the wire was once more determined at the temperature 10° C.

Values of the expression (1) were calculated from both sets of magnetisation observations, and the mean of the two sets compared with the actual contraction observed between them.

The results are shown in Tables II, III, IV, V, VI, in which values of all the quantities (obtained from the corresponding curves) are given for the same set of field strengths.

In Tables II, IV, the first column contains values of the field strength H, the second the magnetisation I at load 4·9 kg., the third the change of magnetisation δI accompanying an increase of load of 7 kg., the fourth the corresponding values of expression (1), *i.e.*, the calculated value of $\delta l/l$. The numbers in the second, third, and fourth columns were determined in November, 1897. The fifth, sixth, and seventh columns contain values of I, δI, and $\delta l/l$, determined in January, 1898.

Tables III and V contain values of the field, the mean values of I and $\delta l/l$ calculated from Tables II and IV, the actual change of length α in millionths, observed about the end of December, 1897, and the difference $(\alpha - \overline{\delta l/l})$ between the observed and mean calculated elongations.

Finally, in Table VI are given the values of I and $\delta l/l$, measured in January; the mean $\bar{\alpha}$ of the actual changes of length observed in December and in January, the latter being determined after the second set of magnetisation measurements; and the difference, $(\bar{\alpha} - \delta l/l)$, representing the corrected elongation at the time when the second set of measurements of I and $\delta\mathrm{I}/\delta\mathrm{P}$ was made.

Tables II and IV show the nature of the slow time-change in the magnetic behaviour of the nickel wire, the magnetisation at any field and load being less in January than in November.

The effect of this change on $\delta\mathrm{I}/\delta\mathrm{P}$ is very marked at low fields, though slight at higher fields; $\delta\mathrm{I}/\delta\mathrm{P}$ appears to diminish rapidly at low fields, as time goes on. This is remarkable, because the magnetic contraction at low fields seemed to change but slowly with time, and more rapidly at higher fields.

The change of length observed in January was nearly the same as in December (about four weeks earlier). At medium fields it was rather greater, but this may be due to a slight annealing caused by the repeated warming and cooling during the determinations of the magnetisation earlier in January.

A comparison of Tables II and IV, or III and V, shows again the nature of the influence of temperature on magnetisation and contraction, but as the measurements at the two temperatures were not made quite at the same time, the results probably do not accurately represent this influence.

If the results given here are compared with those given in the former paper, it will be seen that the magnetic contraction at any field observed in December, 1897 (Table III), is practically identical with the former value, but that the magnetisation curve is very different from the former one. The present magnetisation is much greater at low and medium fields, but about the same as before at higher fields. Further, the calculated value of the contraction is, especially at medium and high fields, considerably less than before. Hence the "corrected" contraction $-(\alpha - \delta l/l)$ cannot now be the same function of the magnetisation as before; it is, in fact, now much more nearly proportional to I^6, as the last two columns of Tables III, V, and VI show.

It is impossible to say how much this discrepancy is due to the slow change which appears to be always going on in the magnetic properties of the nickel wire. In the former experiments the magnetisation was determined first, and a short time after the elongation was observed, but no allowance was made for any change of magnetisation which might have taken place in the meantime. Still, it is improbable that that would entirely account for the discrepancy.

Some of the above results are shown graphically in figs. 1, 2, 3. In fig. 1 the difference of ordinates of the highest and lowest curves for any value of the field H represents the effect on the magnetisation of changing the load from 1·4 kg. to 8·4 kg., after the additional load of 7 kg. has been applied and removed, and the field reversed, several times. The intermediate curve is the magnetisation curve of increasing reversals for the mean load 4·9 kg. These curves were determined in January, 1898.

In fig. 2 the curves represent, as functions of the field, the observed contraction (December, 1897), the calculated contraction (mean of November, 1897, and January, 1898), and the corrected contraction, *i.e.*, the difference between the observed and calculated contractions, The calculated contractions of November and January are represented by the points $+ + + ..$ and $\odot\odot\odot ..$ respectively. The observed contraction curve is practically the same as that given in the former paper, but the calculated and corrected curves show considerable differences.

In fig. 3 the points marked $+ + + ..$ represent the corrected contraction as a function of I^6 (Table III), and these points lie nearly on a straight line through the origin. The temperature during all the experiments represented by these curves was 10° C.

Fig. 1.

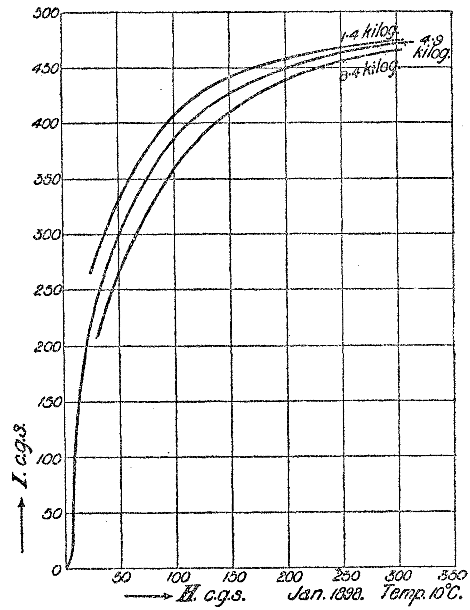
1·4 kilog.
4·9 kilog.
8·4 kilog.
I. c.g.s.
H. c.g.s.
Jan. 1898.
Temp. 10°C.

Fig. 2.

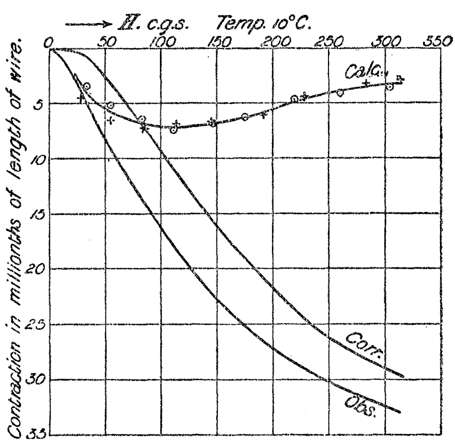
H. c.g.s.
Temp. 10°C.
Calc.
Corr.
Obs.
Contraction in millionths of length of wire.

FIG. 3.

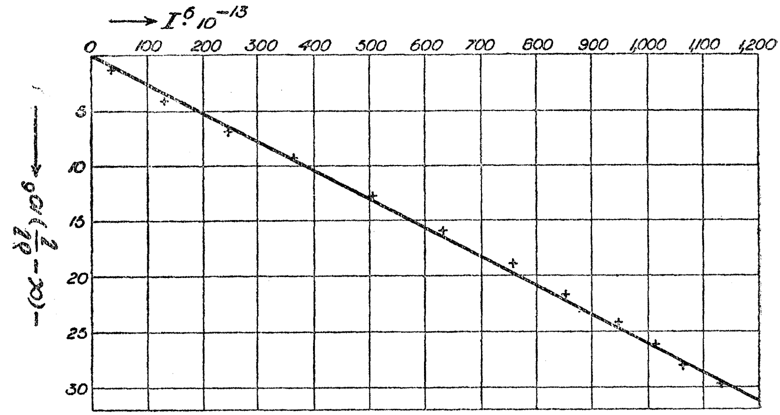

Table I.

Load 4·9 kg. August, 1897.

H.C.G.S.	Contraction of nickel wire in millionths of its length.	
	At 19° C.	At 56° C.
35	7·0	7·5
60	12·5	13·2
80	16·5	16·7
100	20·0	19·6
125	23·6	22·8
150	26·5	25·3
175	29·0	27·6
200	31·4	29·8
225	33·6	31·6
250	35·5	33·3
275	37·0	34·6
300	38·2	35·7
330	39·1	36·8

Table II.

Temperature 10° C. Load = 4·9 kg. $\delta P \times$ Section of Wire = 7 kg.

H.C.G.S.	November, 1897.			January, 1898.		
	I.	δI.	$\frac{\delta l}{l} . 10^6$ calc.	I.	δI.	$\frac{\delta l}{l} . 10^6$ calc.
35	272	−94·5	−5·1	258	−70·0	−3·7
60	340	−73·5	−6·6	323	−60·0	−5·5
80	375	−58·0	−7·1	359	−54·0	−6·45
100	399	−47·0	−7·15	385	−47·5	−7·05
125	419	−38·0	−7·0	409	−38·0	−7·1
150	434	−30·5	−6·7	426	−31·0	−6·7
175	446	−24·0	−6·3	440	−24·0	−6·3
200	454	−19·0	−5·65	450	−18·5	−5·5
225	461	−14·5	−4·6	458	−14·0	−4·65
250	466	−11·0	−4·0	464	−11·5	−4·2
275	470	−9·0	−3·55	468	−9·5	−3·8
310	476	−8·0	−3·15	473	−8·0	−3·5

Table III.

Temperature 10° C. Load = 4·9 kg.

H.	Mean I.	Mean $\frac{\delta l}{l} . 10^6$ calculated.	$\alpha . 10^6$ observed.	$\left(\alpha - \overline{\frac{\delta l}{l}}\right) . 10^6$.	$I^6 . 10^{-13}$.
35	265	−4·40	−5·3	−0·9	34·6
60	331	−6·05	−10·0	−3·95	132·0
80	367	−6·78	−13·35	−6·6	244·0
100	392	−7·10	−16·35	−9·2	363·0
125	414	−7·05	−19·9	−12·8	503·0
150	430	−6·70	−22·8	−16·1	632·0
175	443	−6·30	−25·3	−19·0	756·0
200	452	−5·58	−27·35	−21·8	852·0
225	460	−4·62	−28·9	−24·3	948·0
250	465	−4·10	−30·3	−26·2	1012·0
275	469	−3·70	−31·5	−27·8	1064·0
310	474	−3·30	−32·9	−29·6	1134·0

Table IV.

Temperature 55° C. Load = 4·9 kg. $\delta P \times$ Section of Wire = 7 kg.

H.	November, 1897.			January, 1898.		
	I.	δI.	$\frac{\delta l}{l} . 10^6$. calc.	I.	δI.	$\frac{\delta l}{l} . 10^6$ calc.
35	274	−93·0	−4·8	264	−70·0	−3·65
60	340	−67·0	−6·15	326	−62·5	−5·45
80	372	−55·5	−6·75	359	−55·0	−6·4
100	393	−46·5	−6·8	385	−44·8	−6·75
125	413	−35·0	−6·5	409	−35·5	−6·6
150	427	−27·5	−6·1	425	−27·0	−6·0
175	438	−22·0	−5·55	436	−21·0	−5·45
200	446	−18·0	−5·0	446	−16·8	−4·9
225	453	−14·2	−4·55	453	−12·9	−4·2
250	457	−11·5	−4·1	457	−10·5	−3·65
275	461	−8·3	−3·65	460	−7·5	−3·60

Table V.

Temperature 55° C. Load = 4·9 kg.

H.	Mean I.	Mean $\frac{\delta l}{l} . 10^6$ calc.	$\alpha . 10^6$ obs.	$\left(\alpha - \frac{\delta l}{l}\right)10^6$.	$I^6 . 10^{-13}$.
35	269	−4·2	−5·5	−1·3	37·9
60	333	−5·8	−10·0	−4·2	136·0
80	365	−6·6	−13·3	−6·7	236·0
100	389	−6·8	−16·3	−9·5	347·0
125	411	−6·5	−19·4	−12·9	482·0
150	426	−6·0	−22·2	−16·2	597·0
175	437	−5·5	−24·5	−19·0	697·0
200	446	−4·9	−26·3	−21·4	787·0
225	453	−4·4	−27·8	−23·4	864·0
250	457	−3·9	−29·1	−25·2	911·0
275	460	−3·6	−30·2	−26·6	948·0

Table VI.

H.	January, 1898.		Mean $\alpha \cdot 10^6$ obs.	$\left(\bar{\alpha} - \frac{\delta l}{l}\right)10^6$.	$I^6 \cdot 10^{-13}$.
	I.	$\frac{\delta l}{l} \cdot 10^6$ calc.			
35	258	−3·7	−5·30	−1·6	29·5
60	323	−5·5	−10·1	−4·6	114·0
80	359	−6·45	−13·6	−7·2	214·0
100	385	−7·05	−16·7	−9·6	326·0
125	409	−7·1	−20·2	−13·1	468·0
150	426	−6·7	−23·1	−16·4	598·0
175	440	−6·3	−25·5	−19·2	726·0
200	450	−5·5	−27·5	−22·0	830·0
225	458	−4·65	−29·05	−24·4	923·0
250	463	−4·2	−30·4	−26·2	986·0
275	468	−3·8	−31·6	−27·8	1050·0
310	473	−3·5	−32·9	−29·4	1120·0

"Upon the Structure and Development of the Enamel of Elasmobranch Fishes." By CHARLES S. TOMES, M.A., F.R.S. Received February 7,—Read February 17, 1898.

(Abstract.)

The nature of the hard polished outer layer of the teeth of this group of fishes has been from time to time a subject of discussion, some authors holding that it is enamel, whilst others deny its claim to be so styled.

The author describes its physical, chemical, and histological peculiarities, calling attention to its hardness, its optical properties, its almost entire solubility in weak acids, and to its tubularity, in all of which respects it resembles unquestionably an enamel.

But it contains lacunar spaces, and presents a very distinct lamination, parallel, or nearly so, with its surface, in which respect it is unlike an enamel.

Still upon the balance of its characters it has much more in common with enamel than with dentine, from which it is sharply marked off by the entire absence of any collagen basis.

It is also shown that the tubular structure, which may be regarded as typical in these fish, passes by insensible gradations into a simple tissue differing but little from an ordinary enamel; this is especially the case where the whole layer is thin, as in the Rays. But the study of its development raises the difficulty afresh.